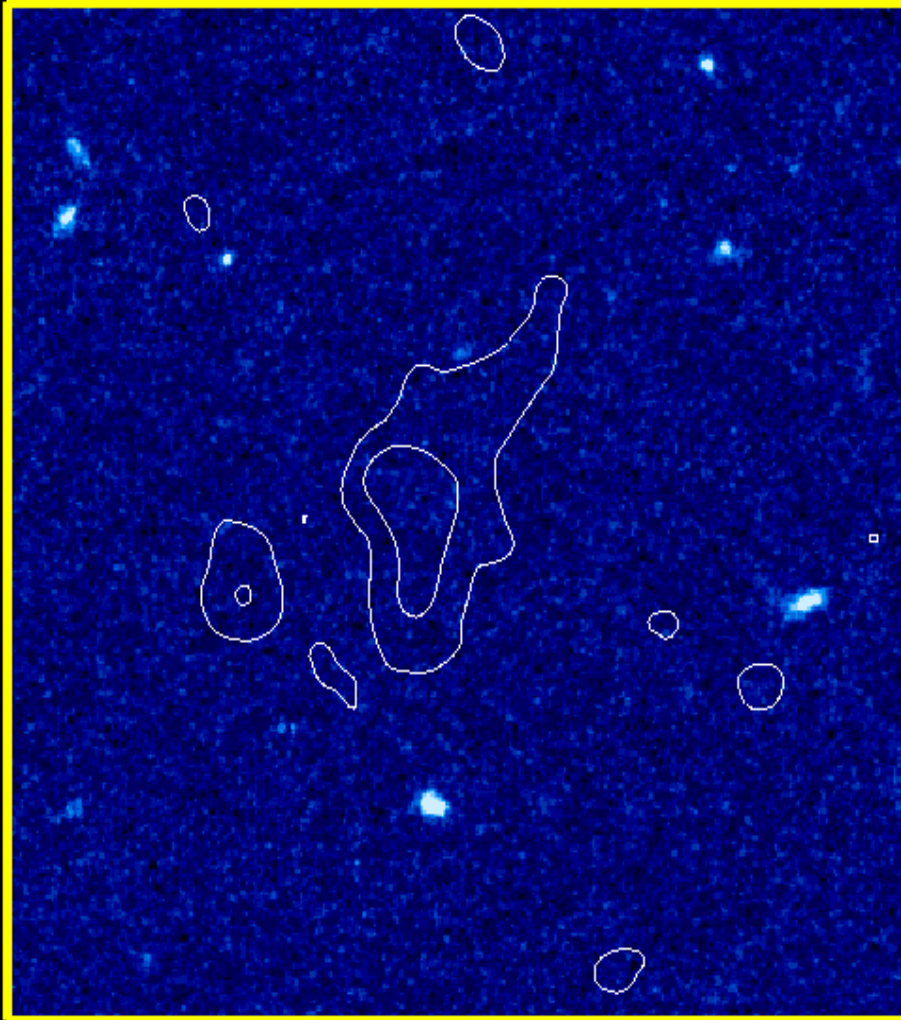
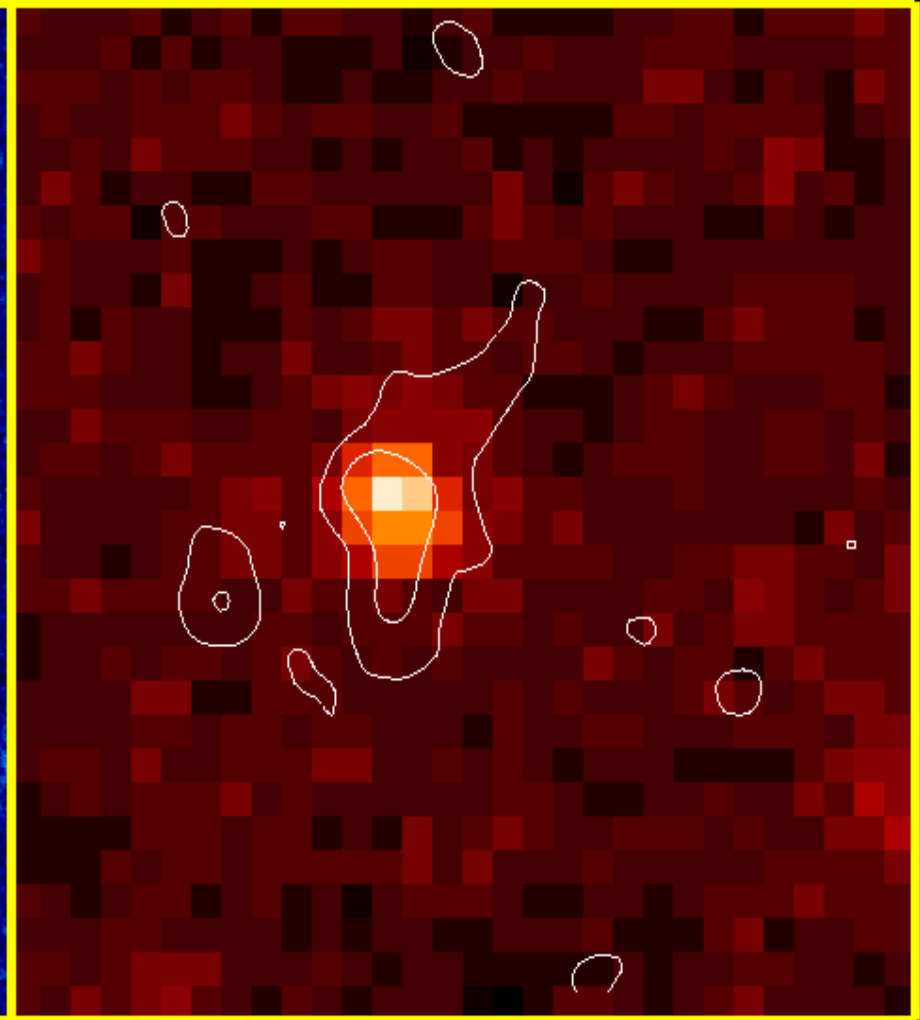


Hubble/ACS (F850LP)



Spitzer/IRAC (5.8 μ m)



Anton Koekemoer, Mark Dickinson, and the GOODS Team

Early Results from the Spitzer Space Telescope

Michael Werner

June 7, 2004



The Spitzer Space Telescope



- ◆ Multi-purpose observatory cooled passively and with liquid-helium for astronomical observations in the infrared
- ◆ Launched in August 2003 for a **5+** year mission in solar orbit
- ◆ Three instruments use state-of-the-art infrared detector arrays
- ◆ Provides a >100 fold increase in infrared capabilities over all previous space missions
- ◆ Completes NASA's Great Observatories
- ◆ Major scientific and technical contributor to NASA's Origins Theme
- ◆ An observatory for the community. ~600 proposals for General Observer Cycle 1 received and evaluated.

**Assembled SIRTf Observatory at
Lockheed-Martin, Sunnyvale.**

Key Characteristics:

Aperture – 85 cm

Wavelength Range - 3-to-180 μ m

Telescope Temperature – 5.5K

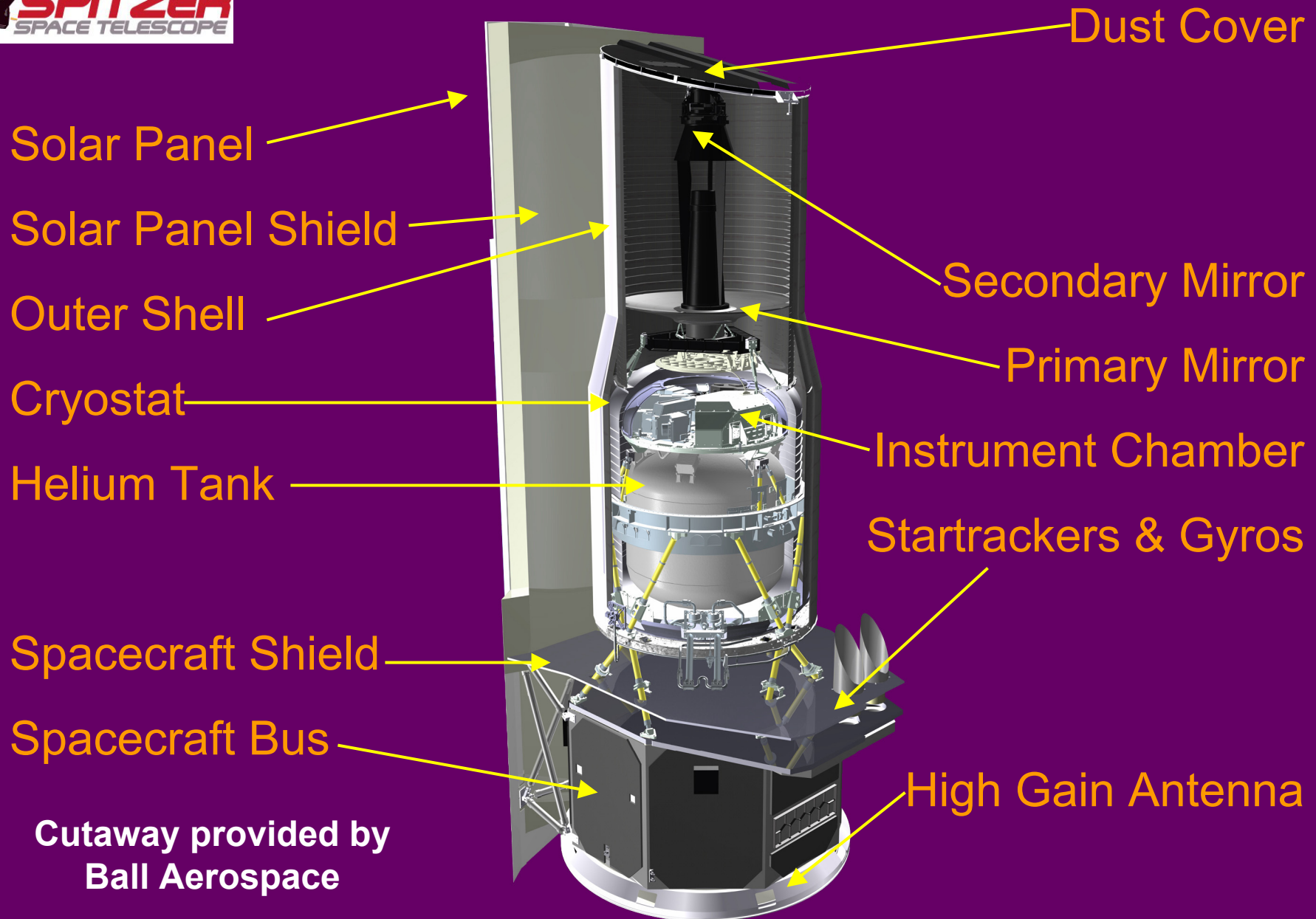
Mass – 870kg

Height – 4m





Cutaway View of the Spitzer Space Telescope



Cutaway provided by
Ball Aerospace

Spitzer's Instruments and Principal Investigators



IRS

[infrared
spectrograph]

J.Houck
Cornell

MIPS

[multiband
imaging
photometer]

G.Rieke
Arizona



IRAC

[infrared
array
camera]

G.Fazio
Harvard/
SAO



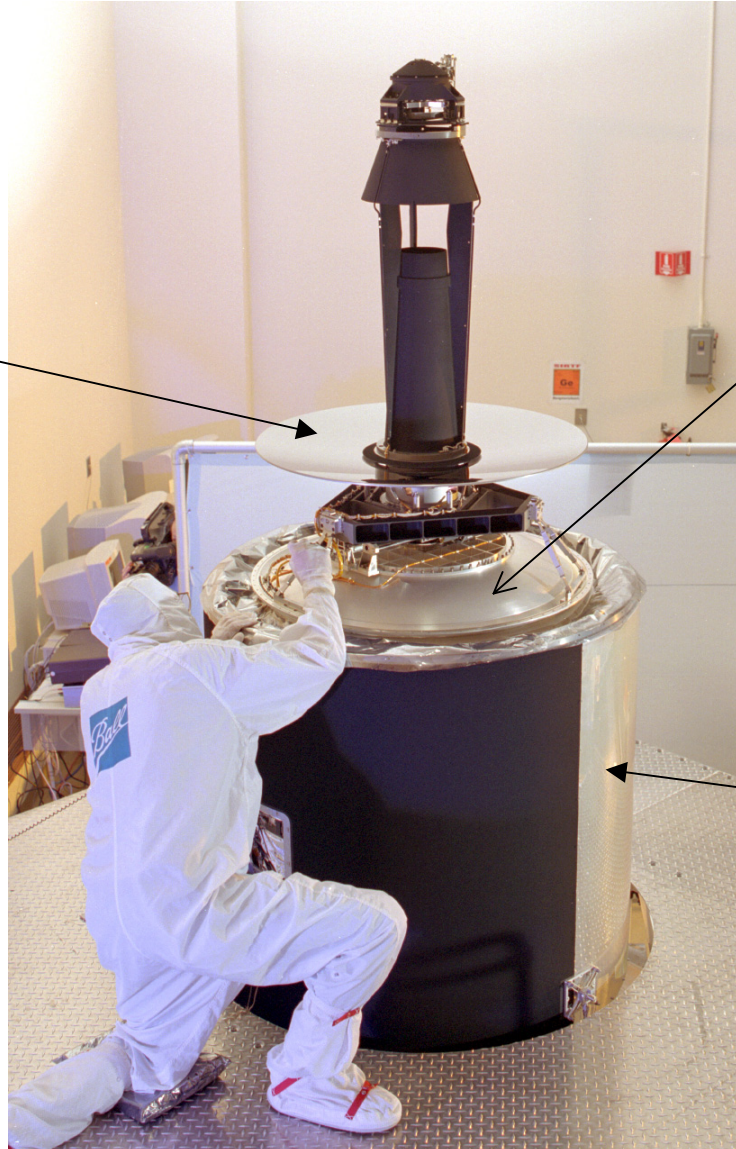
Spitzer Space Telescope
**Assembly of the Heart of
the CTA**



**Telescope
Primary
Mirror**

Cryostat Dome

**Lower Portion of
Outer Shell**





Spitzer Space Telescope

Completion of the Assembly of the Outer Shell





Spitzer Space Telescope
The Spitzer Observatory
Fully Assembled

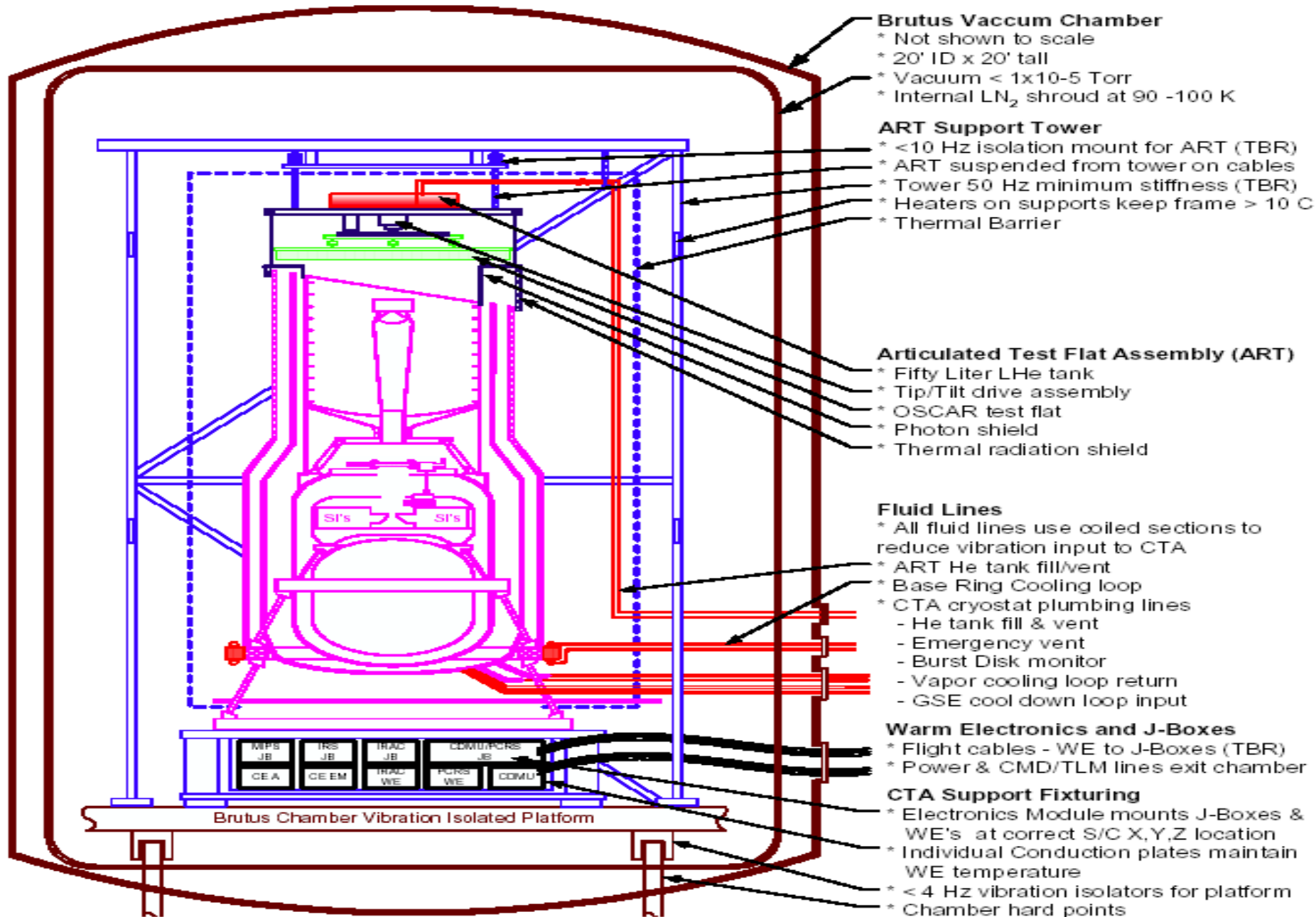




Spitzer Space Telescope

Hoisting the CTA into the Thermal Test Chamber





Spitzer CTA Performance Test Configuration



SPITZER AT THE CAPE





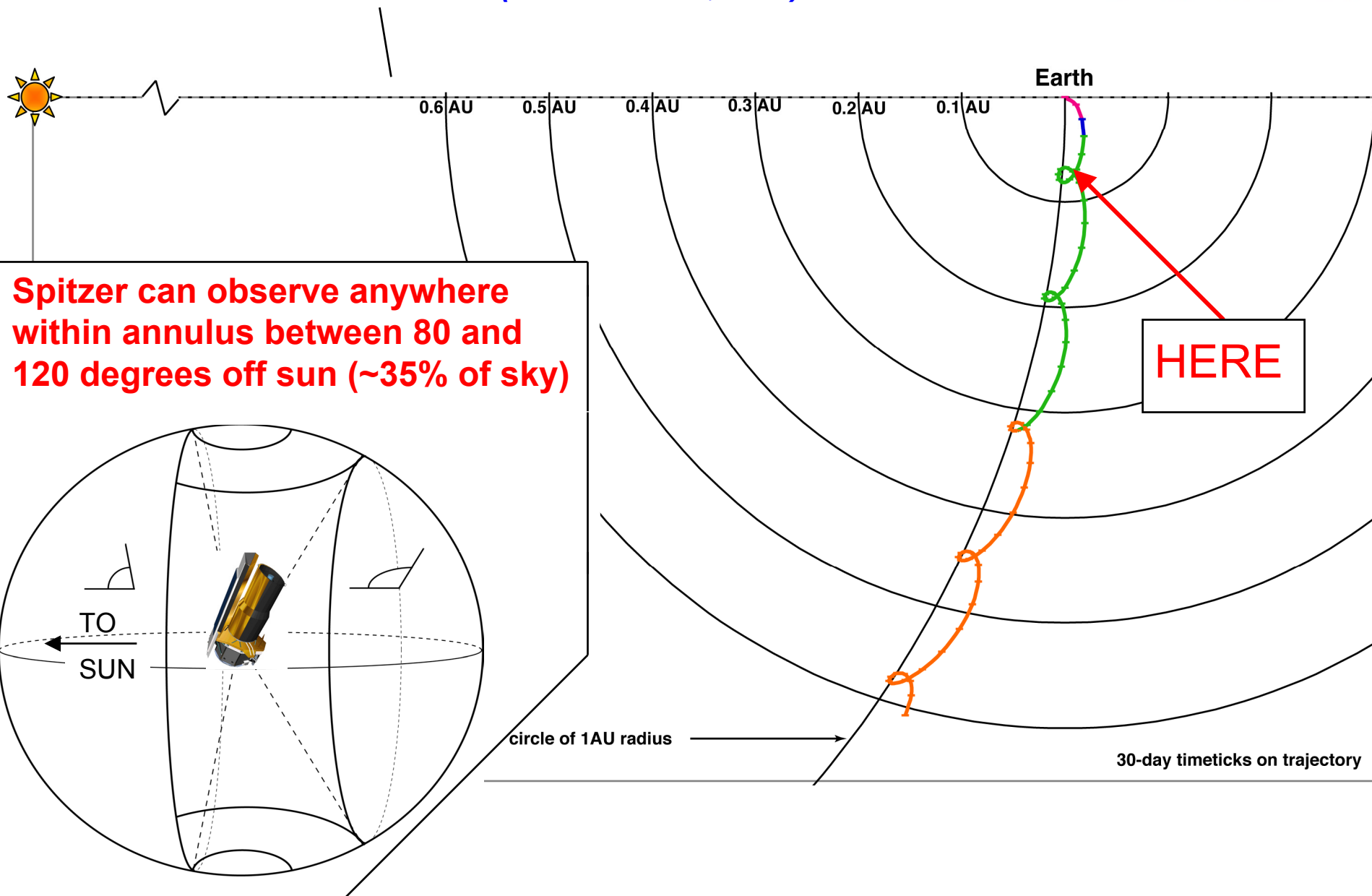
August 25, 2003- WE'RE OFF!





Where's Spitzer Now?

(Mark Garcia, JPL)





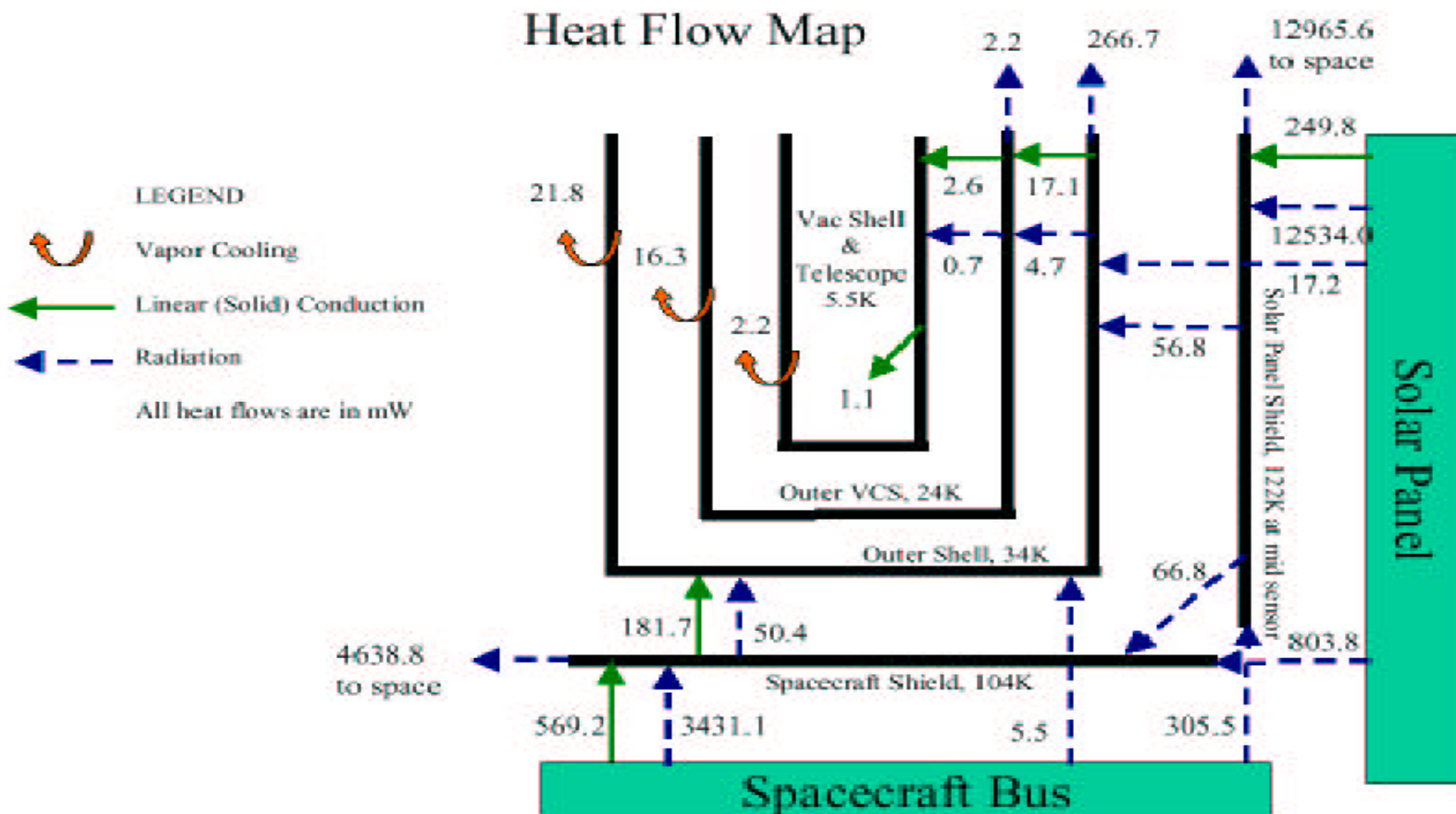
Spitzer Cryo-Thermal System – Key Design Features



- **High reflectivity shields and shells to minimize heat input to outer shell**
 - *Aluminized Kapton face sheets on Graphite/composite cores*
- **Ball Infrared Black paint on anti-solar sun of outer shell**
 - *Emissivity higher than expected at on-orbit temperature*
- **Thin, low conductivity cables to minimize conductive heat load**
 - *Heat sunk and vapor cooled, about 1500 separate conductors and many connectors*
- **Photon shutter within cryostat – stowed before launch – to minimize heat load and reduce boil-off before launch. Low emissivity window in aperture door allowed optical tests pre-launch**
- **GSE cooling loop permitted outer shell temperature to be driven down for ground test**
- **360 l. He tank with 49Kg SfHe (93.5% full) at launch; 43Kg at L+60 days**
- **Two radiation shields within cryostat for ground hold purposes**
- **Make-up heater within He tank for temperature control**
- **Very well balanced low thrust vents**
- **<1mw parasitic load on orbit**



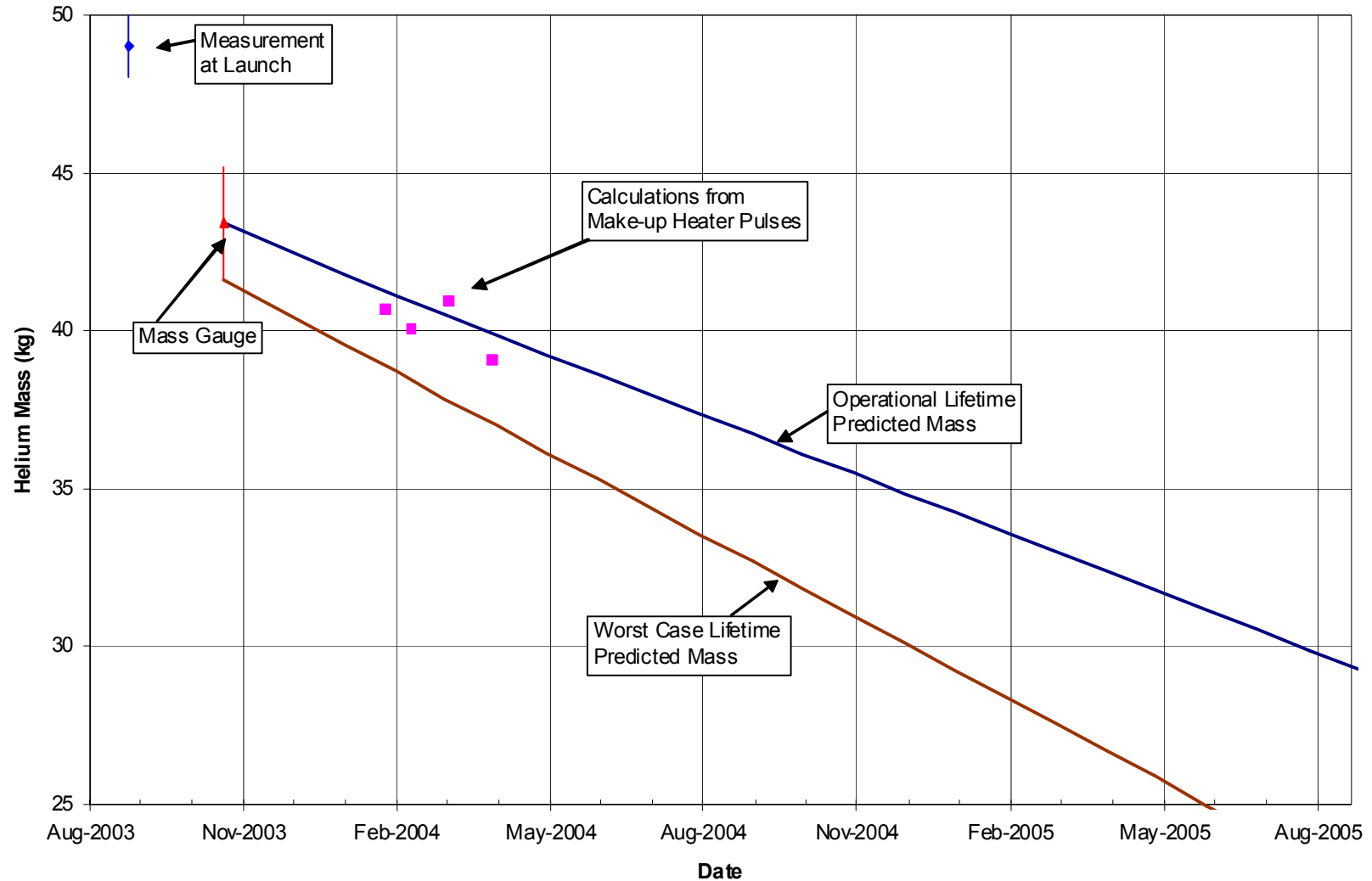
Spitzer – on orbit heat flow



Flight-Correlated Model
December 2003



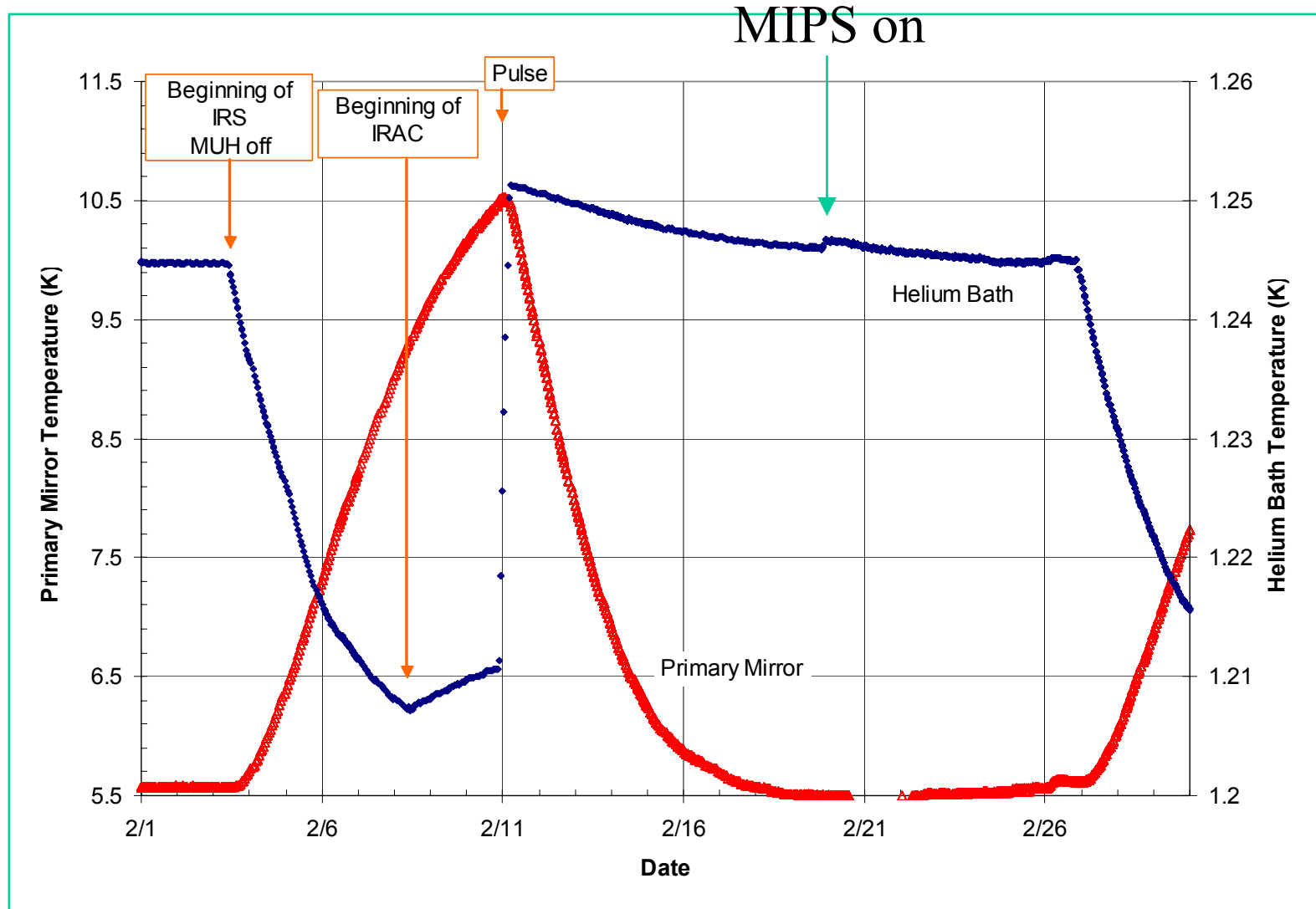
Helium lifetime tracking 5.8* yr, post-launch, predictions



* Prediction includes 10% operational enhancement



Pulse Method to Enhance Lifetime is Being Successfully Implemented





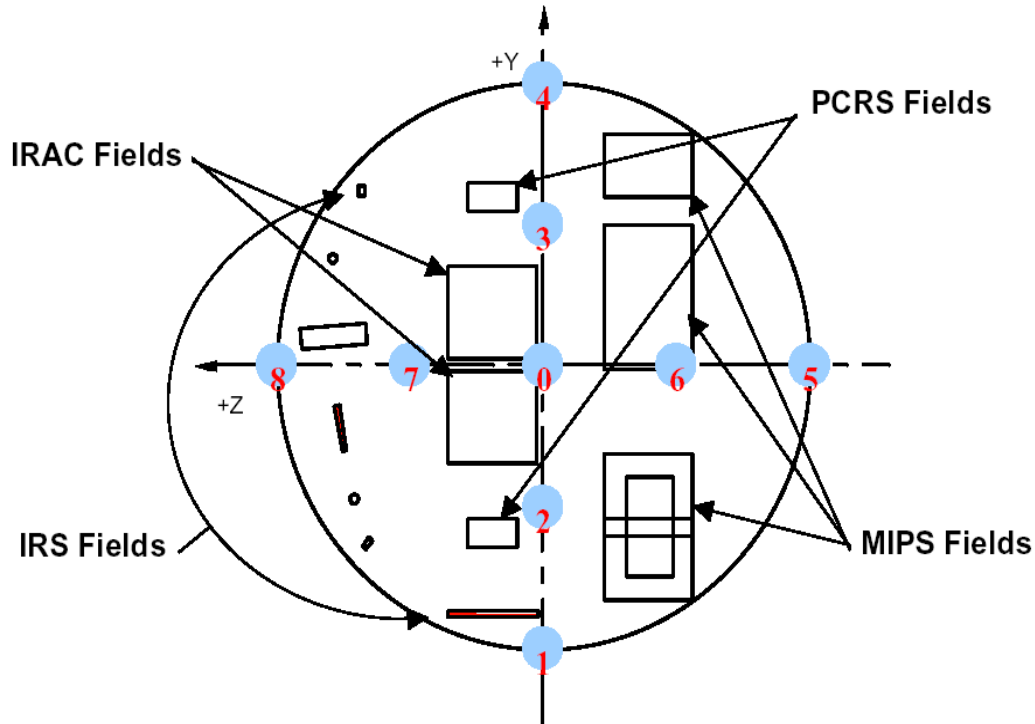
Spitzer Optical System – Key Features



- **85-cm diameter, all-Beryllium telescope: mass = 55Kg**
- **One-dimension focus mechanism with throw at focal plane of +/- one inch and step size at focal plane of a few hundred microns**
 - *Focus criteria and procedures defined and practiced carefully before launch*
- **Primary mirror tested cold repeatedly and reproducibly. Primary subjected to two “cryo-null” polishing cycles**
 - *Secondary mirror not separately tested*
- **Opto-mechanical fiducials on instruments were used to establish confocality of instruments and PCRS after installation and cooldown in cryostat**
 - *Alignment maintained throughout system buildup via carefully crafted alignment plan*
 - *Ambient temperature optical tests used to monitor alignment during shipping, etc.*
 - Windows in dust cover allowed partial verification of alignment at Cape
- **End-end optical test with system cold in Brutus verified image quality, focus position, and confocality**
- **Light sources in the cold focal plane for ground use only to permit image test by auto-collimation and to monitor instrument aliveness**
- **Window in aperture door permitted alignment and image quality to be assessed with cryostat outer shell warm.**



Predicted Wave Front Error Across the Spitzer Focal Plane



Requirement is 0.464 micron, corresponding to 6.5um diffraction limit. On orbit performance is better than 5.5um diffraction limit over IRAC field

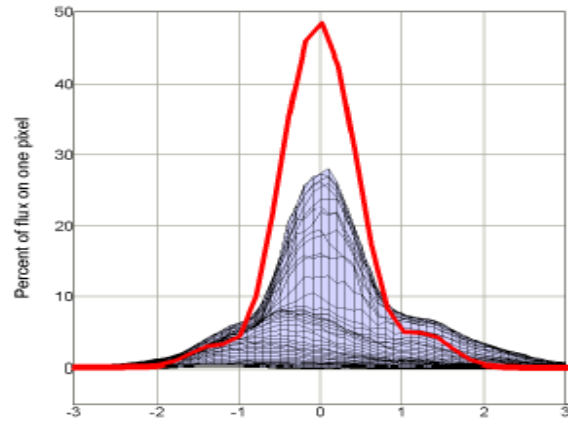
| Field Point | Predicted On-Orbit Wavefront |
|-------------|------------------------------|
| | (microns rms) |
| 0 | 0.300 |
| 1 | 0.441 |
| 2 | 0.314 |
| 3 | 0.321 |
| 4 | 0.459 |
| 5 | 0.371 |
| 6 | 0.300 |
| 7 | 0.308 |
| 8 | 0.426 |



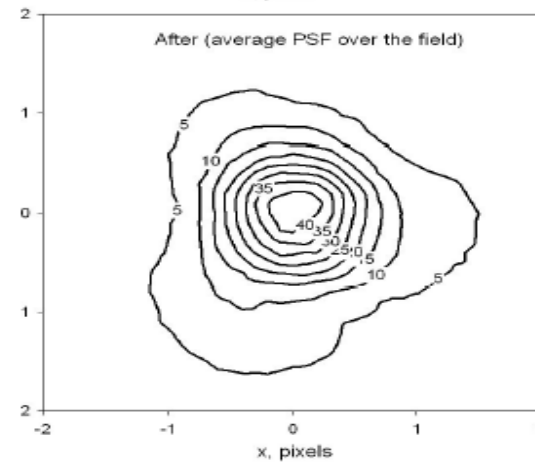
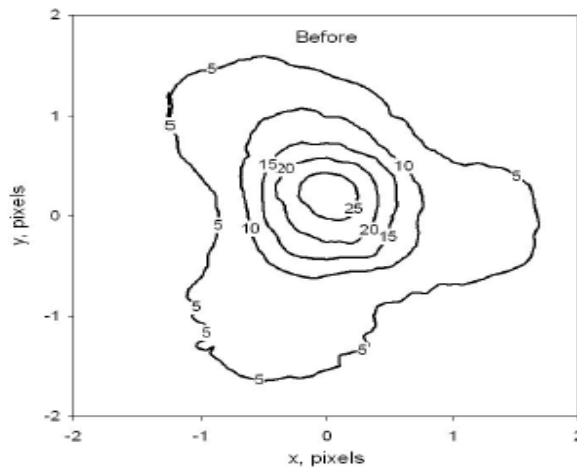
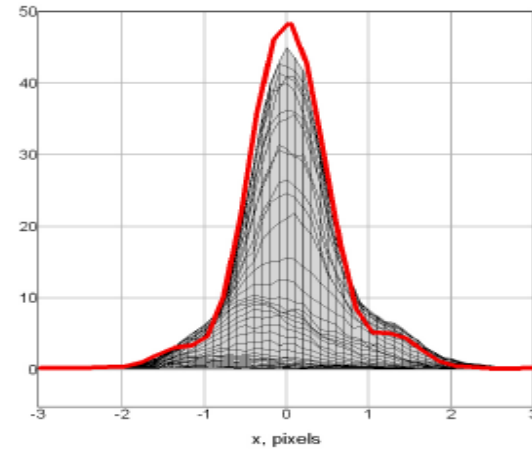
Effects of Focussing Spitzer at 3.6um



Before



After





Surface Plots of the IRAC Oversampled PSFs for all 4 IRAC Channels After Focus



3.6 μm

4.5 μm

5.8 μm

8 μm

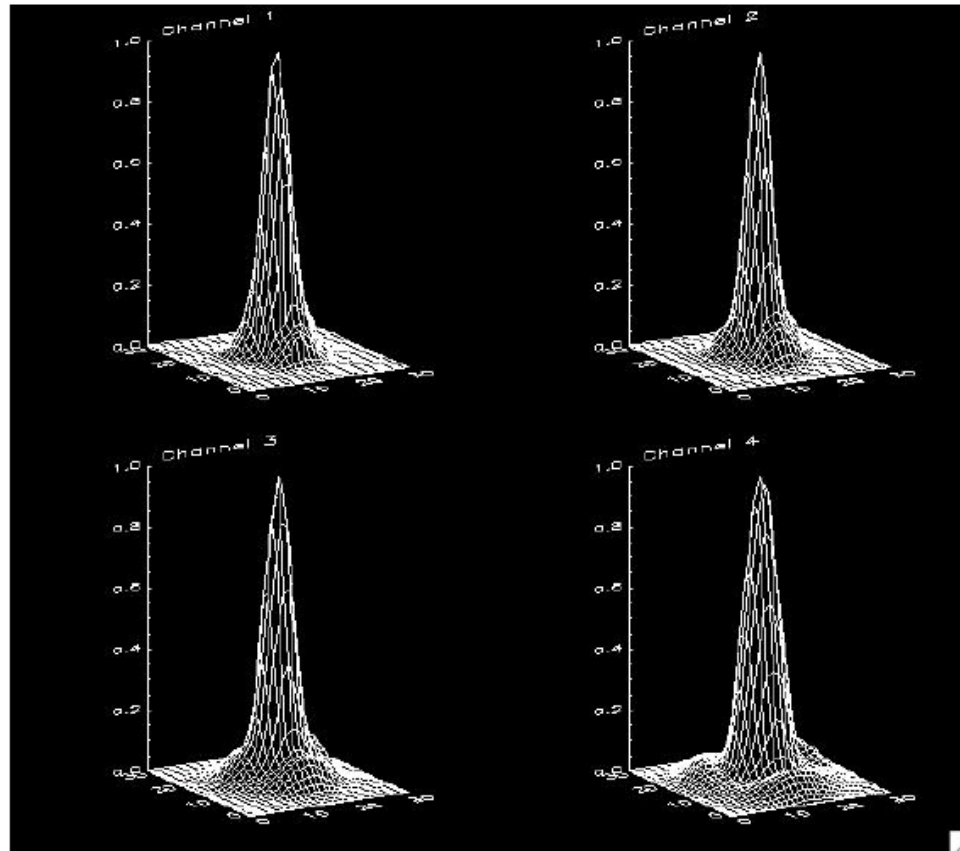


Figure 2-3. Surface plots of the Drizzle-reconstructed PSFs. Each plot has been normalized to 1.

(Dave Elliott, JPL)

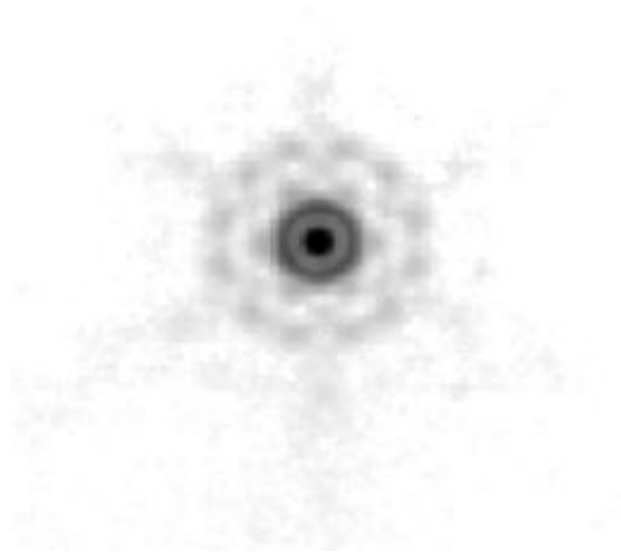


Spitzer Space Telescope

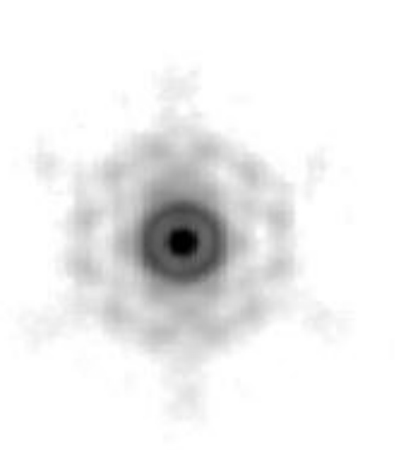
24um Point Spread Functions (K. Stapelfeldt, MIPS/JPL)



Tiny Tim
Prediction



On-orbit
measured



Fomalhaut



Spitzer Pointing and Control System – Key Design Features



- **Very capable 5x5 sq degree autonomous star tracker with NEA~0.11 arcsec when tracking 35 stars**
- **Redundant Kearfott IRU [gyros] and Ithaco Reaction Wheel Assemblies**
- **Pointing and Control Reference Sensor [PCRS] – Visible wavelength Silicon diode array – in cold focal plane to maintain telescope/star tracker boresight alignment**
- **Peakup arrays in IRS to facilitate placing science targets on spectrograph slits. PCRS can also be used in this fashion.**
- **Cold N₂ gas system used to dump angular momentum accumulated in RWA's**
 - *Contamination and leaky thrusters were a big problem before launch*
- **Solar system target tracking at rates in excess of 0.1 arcsec/sec**



On-orbit Pointing System Performance

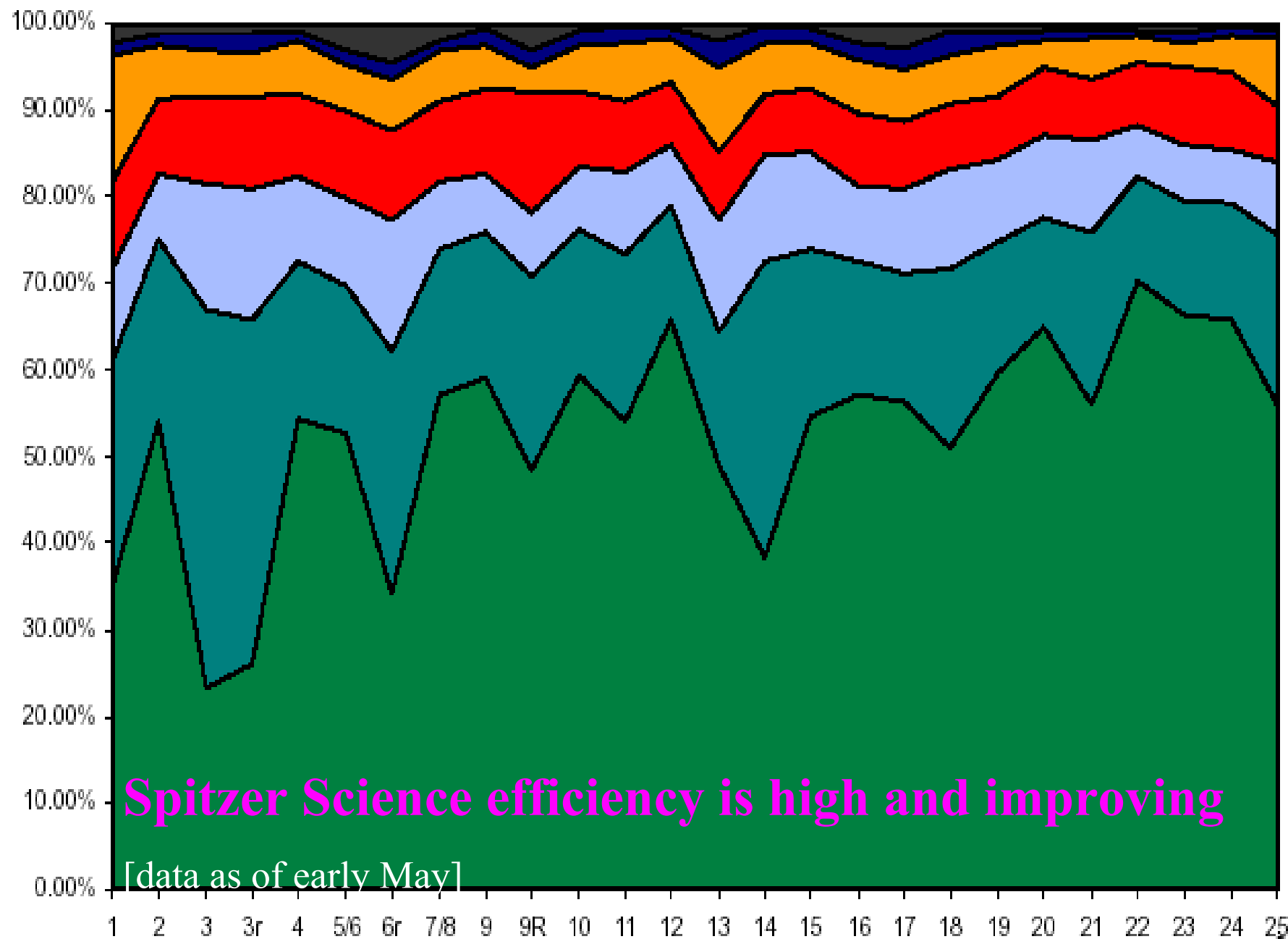
preliminary assessment

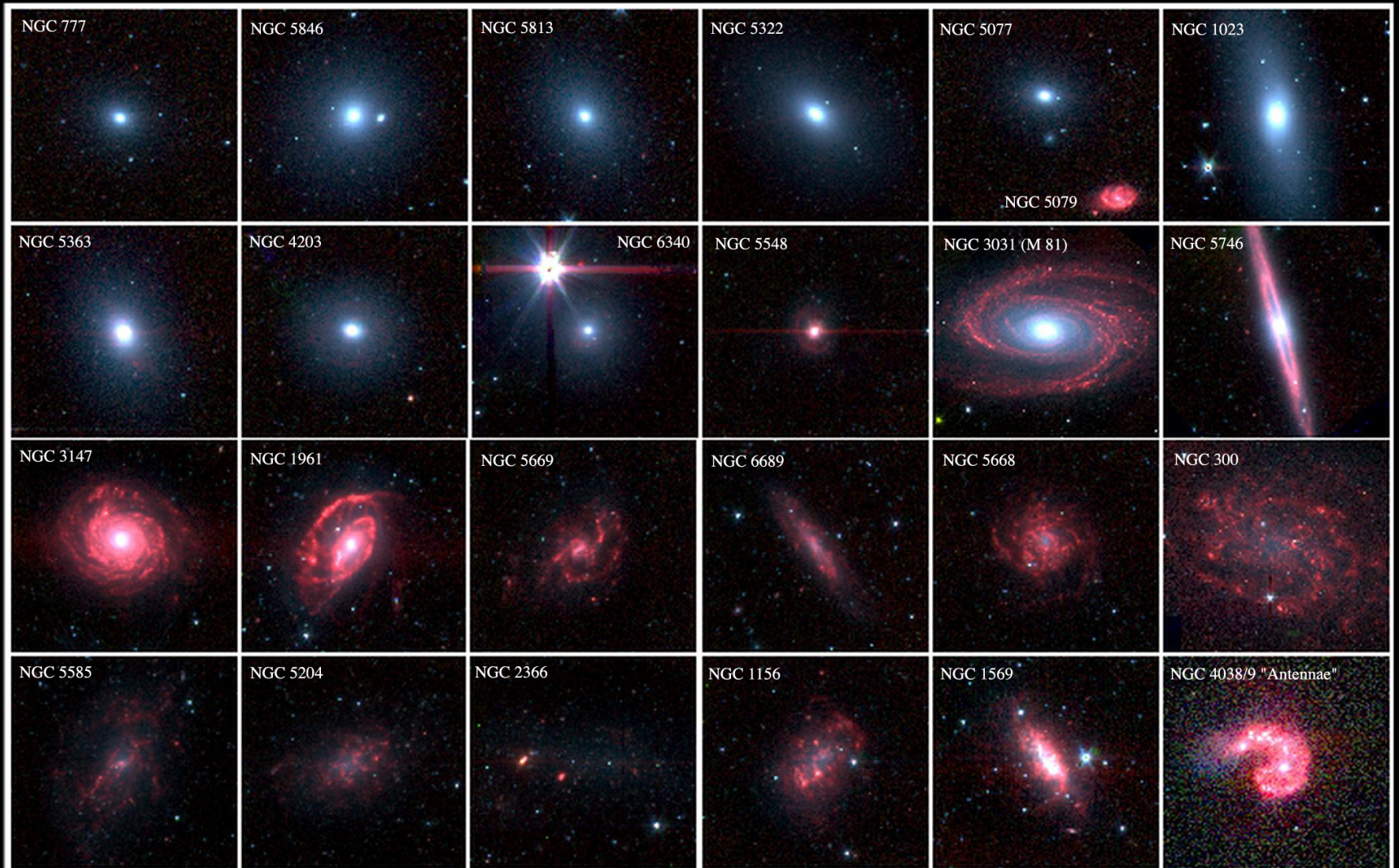


| Parameter | Requirement | Actual | Units |
|------------------------------|---------------------|---|------------------------|
| Stability over 200 s..... | 0''3 | 0''03 | 1 σ radial, rms |
| Stability over 600 s..... | 0''6 | 0''03 | 1 σ radial, rms |
| Blind pointing..... | 5'' | 1''4 [sometimes <1''] | 1 σ radial |
| Offset pointing (<30') | 2'' [QP] | OK | 1 σ radial |
| | 1'' [HP2] | OK (maybe even point & shoot) | |
| | 0''4 [HP1] | Not finished yet. Short-term gyro drift is the issue. Alignment good. Handoff time can be but has not yet been optimized. | |
| Moving object tracking..... | $\leq 1''/\text{s}$ | OK so far, up to 200''/hr | |
| PCRS | 0''14 over 2'' | Better close, worse further out | |
| Star tracker accuracy | 0''6 | 0''2 | 1 σ per axis |
| NEA | 0''22 | 0''106–0''117 | |
| rotation NEA | 6''2 | 2''5 | |
| Focal plane survey | various | IRAC & IRS OK with margin. MIPS TBD. | |

- Star trackers better than expected; gyros worse. Handoff time will be adjusted.
- Overall, very good. Areas being worked will not interfere with science.

Science SI Cals Slews Downlinks S/C Cals Conflicts Halts Gaps





Infrared Mosaic of Nearby Galaxies

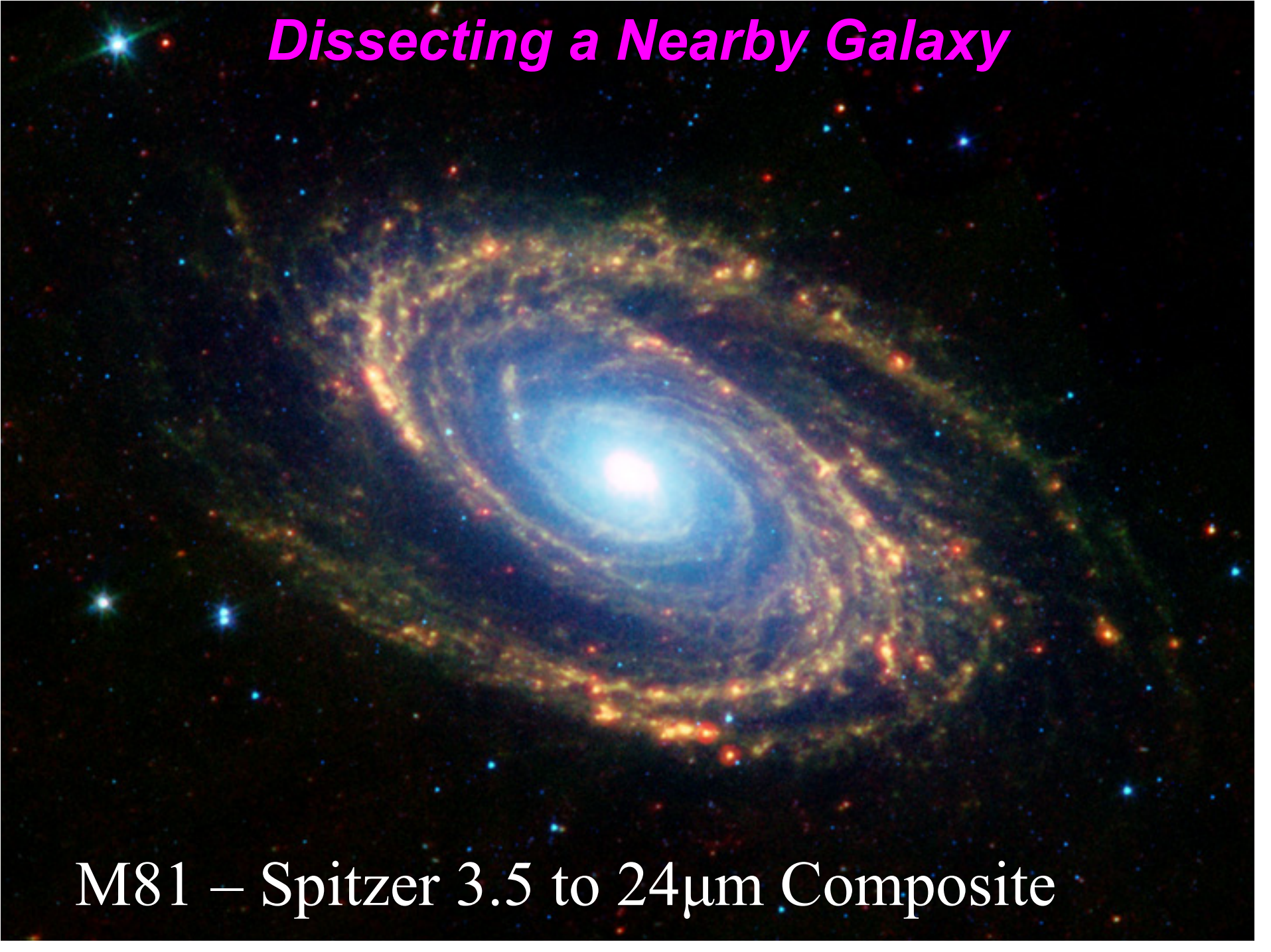
Spitzer Space Telescope • IRAC

M. A. Pahre & G. G. Fazio (SAO) / NASA / JPL-Caltech

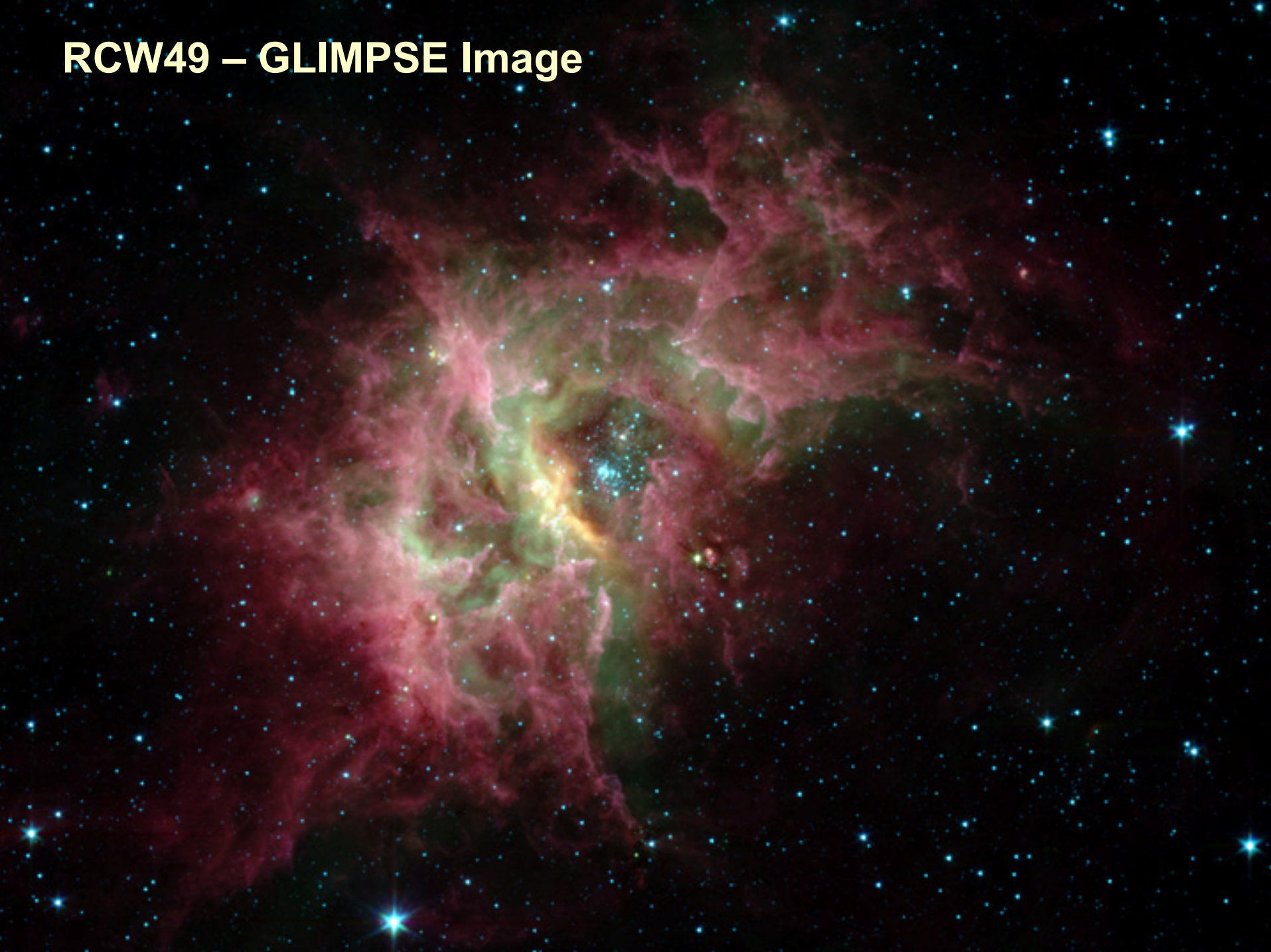
sao-2004-19

Dissecting a Nearby Galaxy

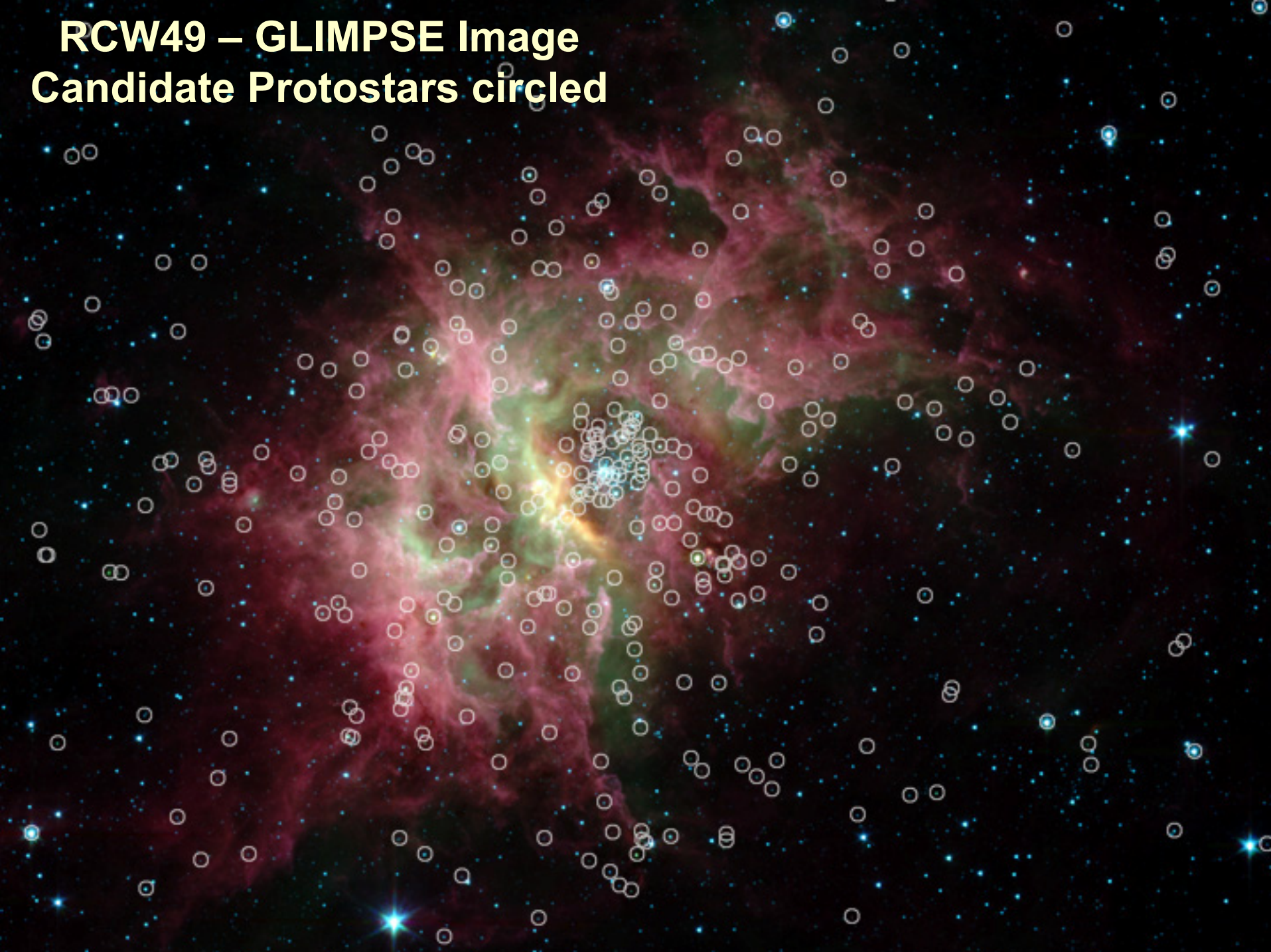
M81 – Spitzer 3.5 to 24 μ m Composite



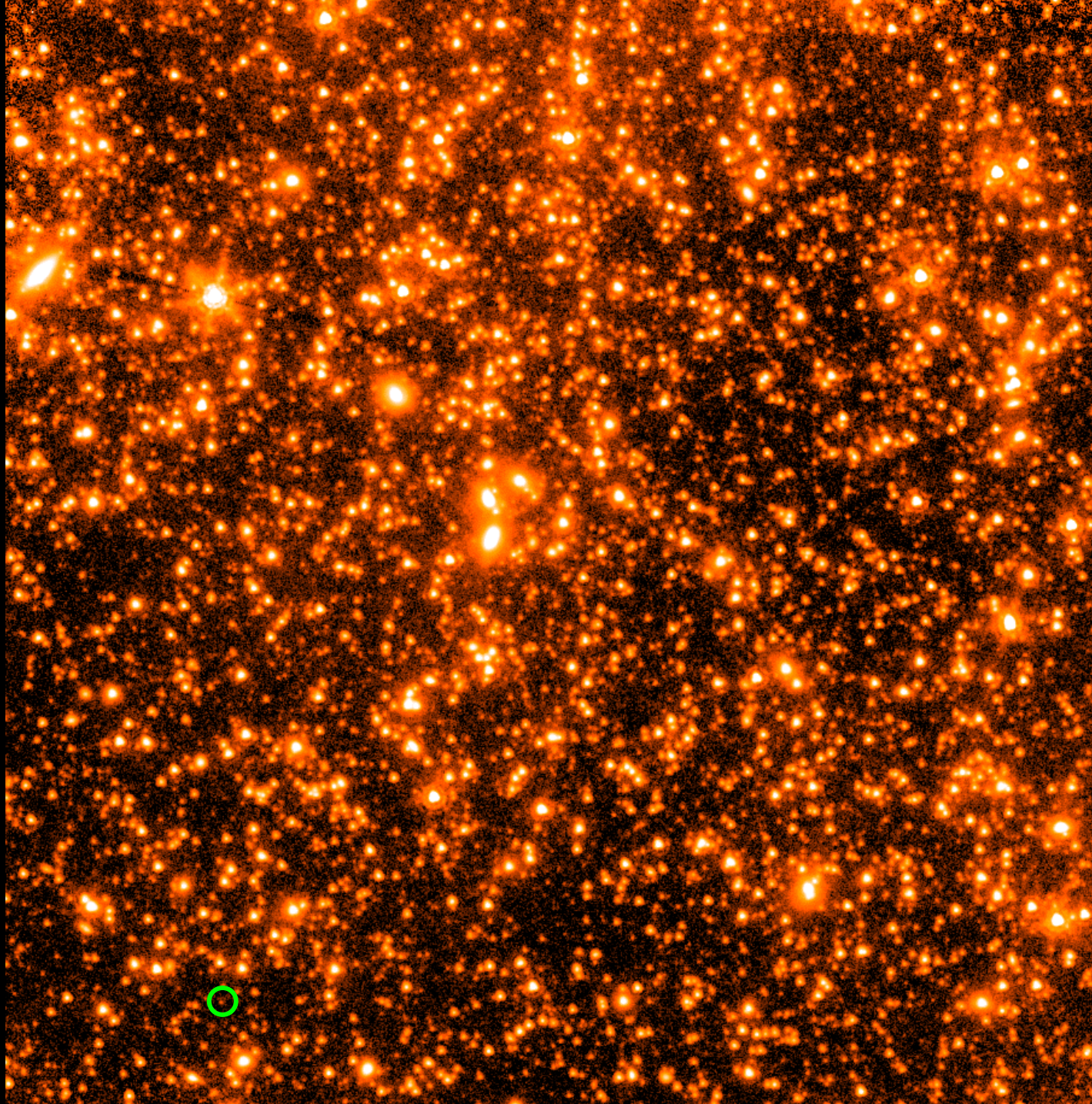
RCW49 – GLIMPSE Image



RCW49 – GLIMPSE Image
Candidate Protostars circled



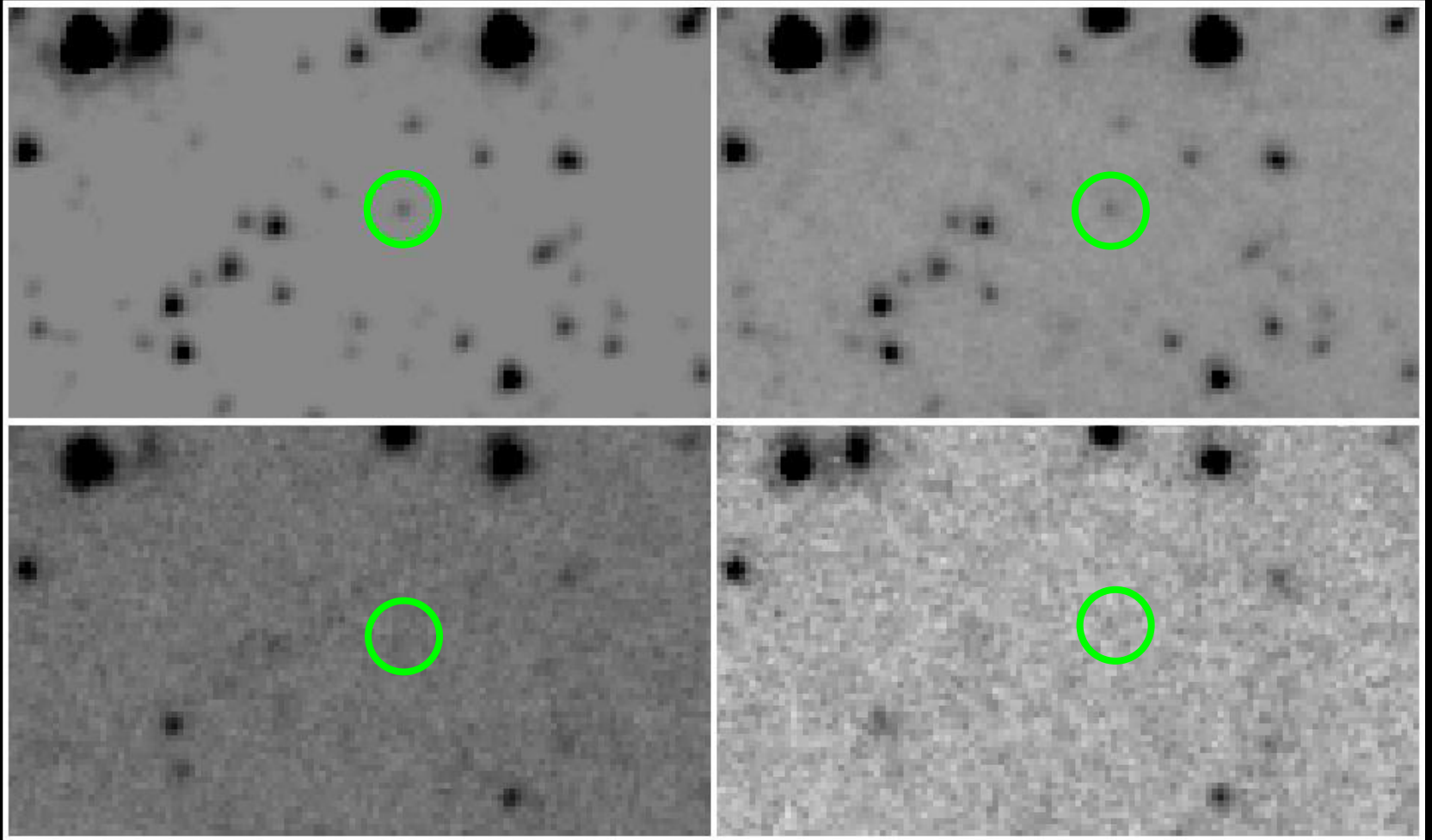
GOODS CDF-S
IRAC 4.5 μm
Feb. 2004
23 hours/point
10 x 10 arcmin



Spitzer Looks Back in Time and Space

3.6 μm

4.5 μm



8 μm

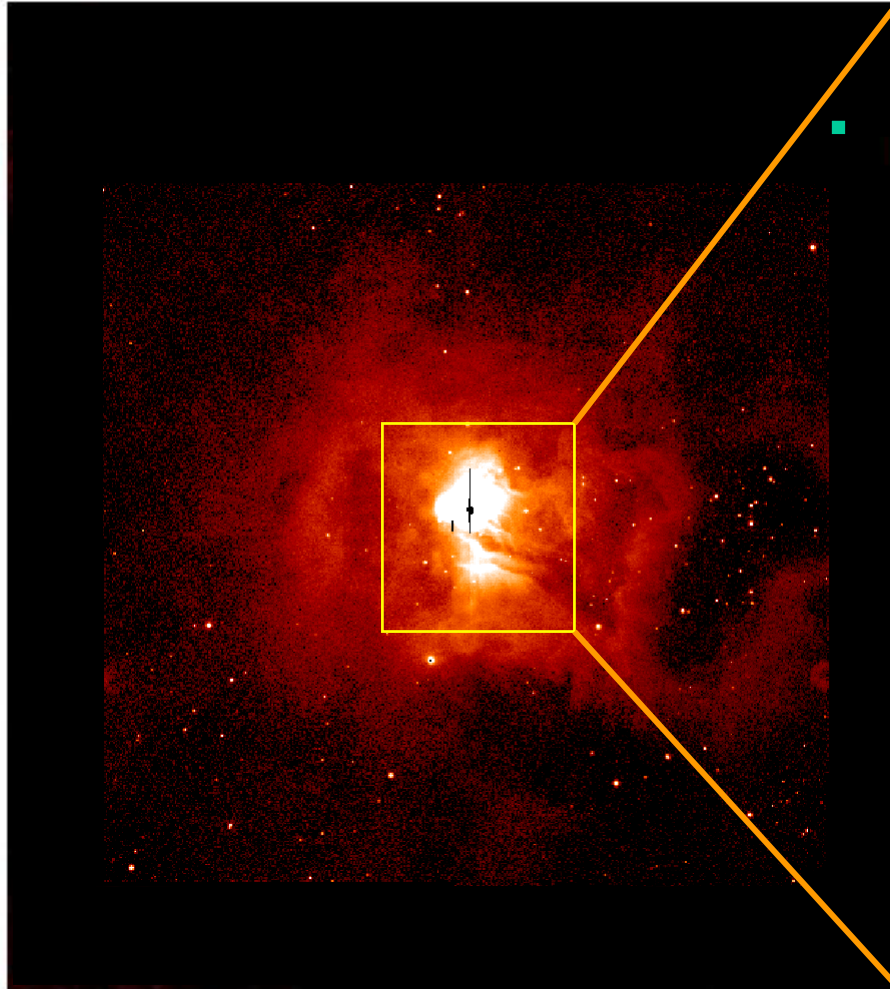
$z=5.8$ galaxy

5.8 μm

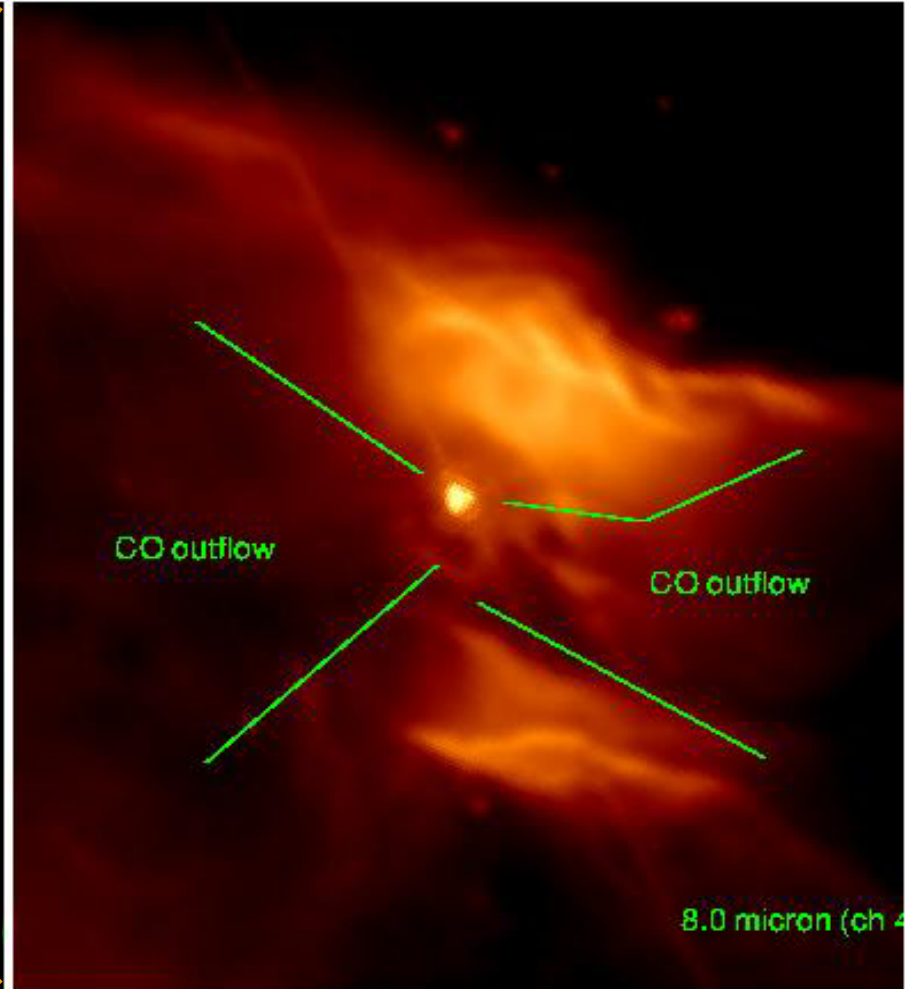


Spitzer Space Telescope
Reflection Nebula NGC7023 –
Visible and IRAC Images

(K.Gordon, MIPS/Arizona & M.Marenco, IRAC/SAO)

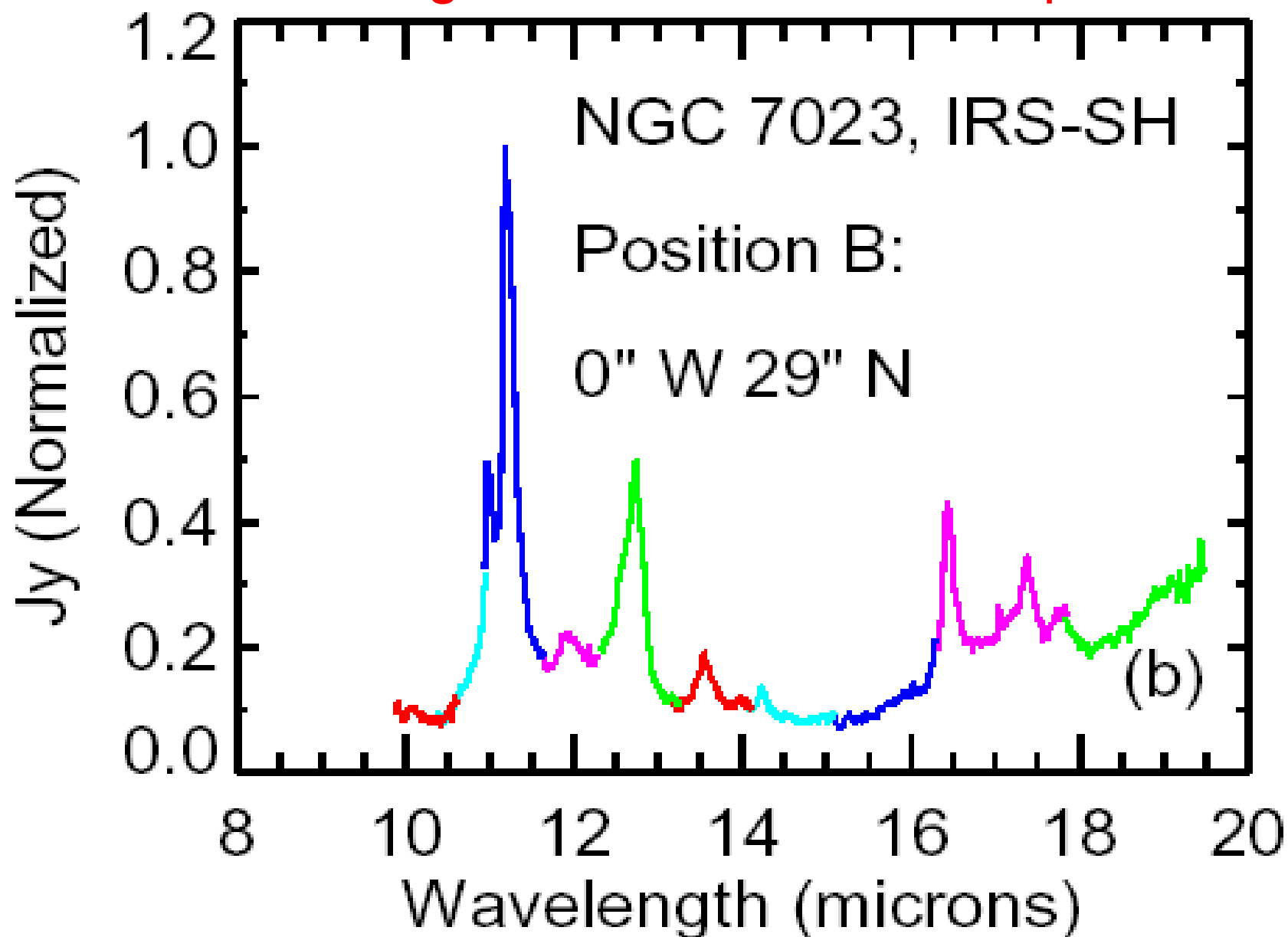


Visible



8 um

NGC7023: High resolution 10-20um spectrum

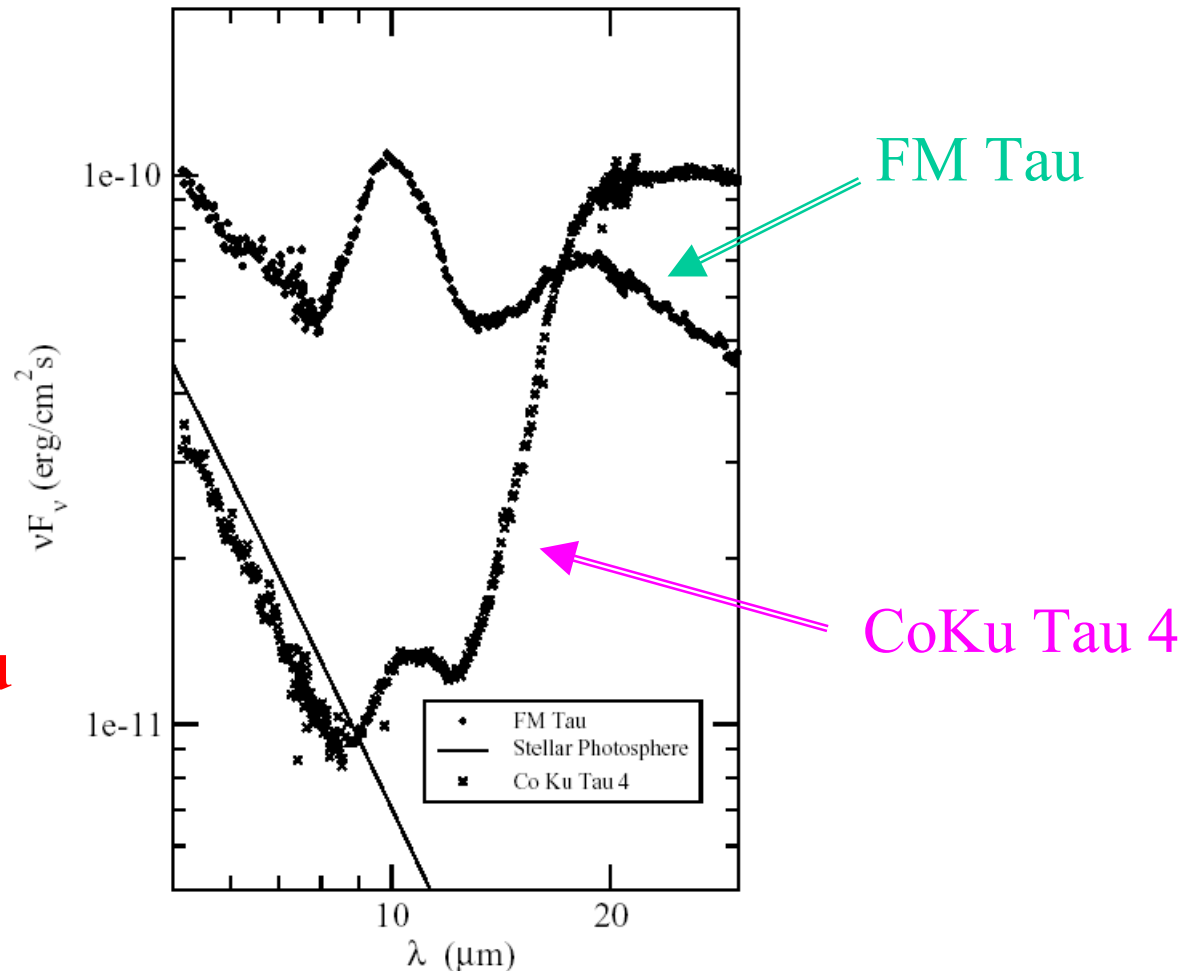




Spitzer Spectra of T Tauri stars (Forrest, Watson et al)



CoKu Tau 4 spectrum shows evidence of central clearing, perhaps due to formation of a planet about 6au from the star.





Recent and Upcoming Science Milestones



- **Spitzer data archive opened, mid-May**
- **Results of first GO selection announced 28 May**
- **Denver AAS Meeting – 31 May – 3 June**
 - *Special Spitzer Session – all day on Tuesday 2 June*
 - *Numerous Spitzer related press releases, including joint Spitzer-Hubble release on GOODS results*
- **First Spitzer papers posted on SSC website and Astro-Ph starting June 1**
- **[You are here!]**
- **Special Spitzer issue of Astrophysical Journal Supplements, September 1**
- **First Spitzer Science conference, Pasadena, November 9-12.**
- **Cycle 2 Call for proposals – issued November 2004, due February, 2005**
 - *We invite you to share the excitement of Spitzer!*

The SIRT
Science Working
Group. First
Meeting,
Summer, 1984



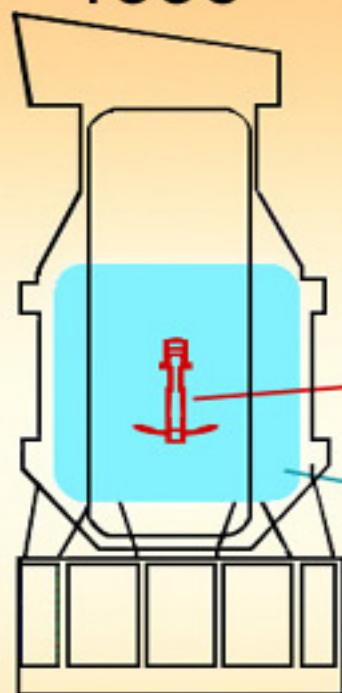
The Spitzer Science Working Group (2004):

| | | | |
|-----------------|----------------|------------------|------------|
| Dale Cruikshank | Giovanni Fazio | Bob Gehrz | |
| Jim Houck | Mike Jura | Charles Lawrence | |
| Frank Low | George Rieke | Marcia Rieke | |
| Tom Roellig | Tom Soifer | Mike Werner | Ned Wright |



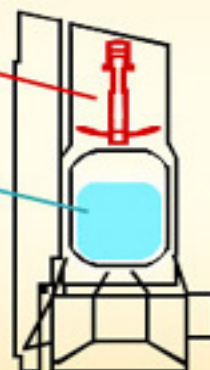
DESIGN CHANGES

1990



COLD LAUNCH

2003



WARM LAUNCH

| | | |
|------------------|----------|---------|
| Launch Mass | 5700 kg | 870 kg |
| Lifetime | 5 years | 5 years |
| Development Cost | ~\$2.2B | \$0.67B |
| Launch Vehicle | Titan IV | Delta |

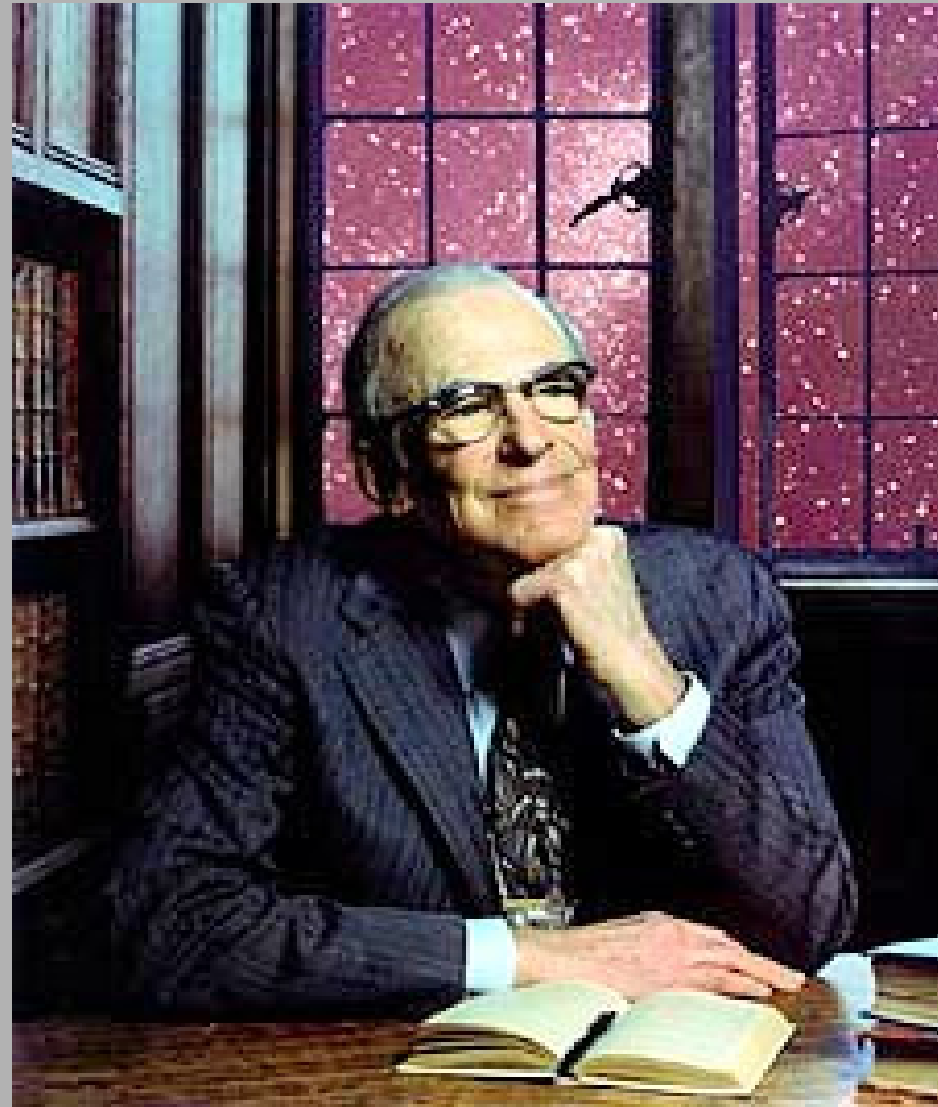
The Spitzer Space Telescope Mission

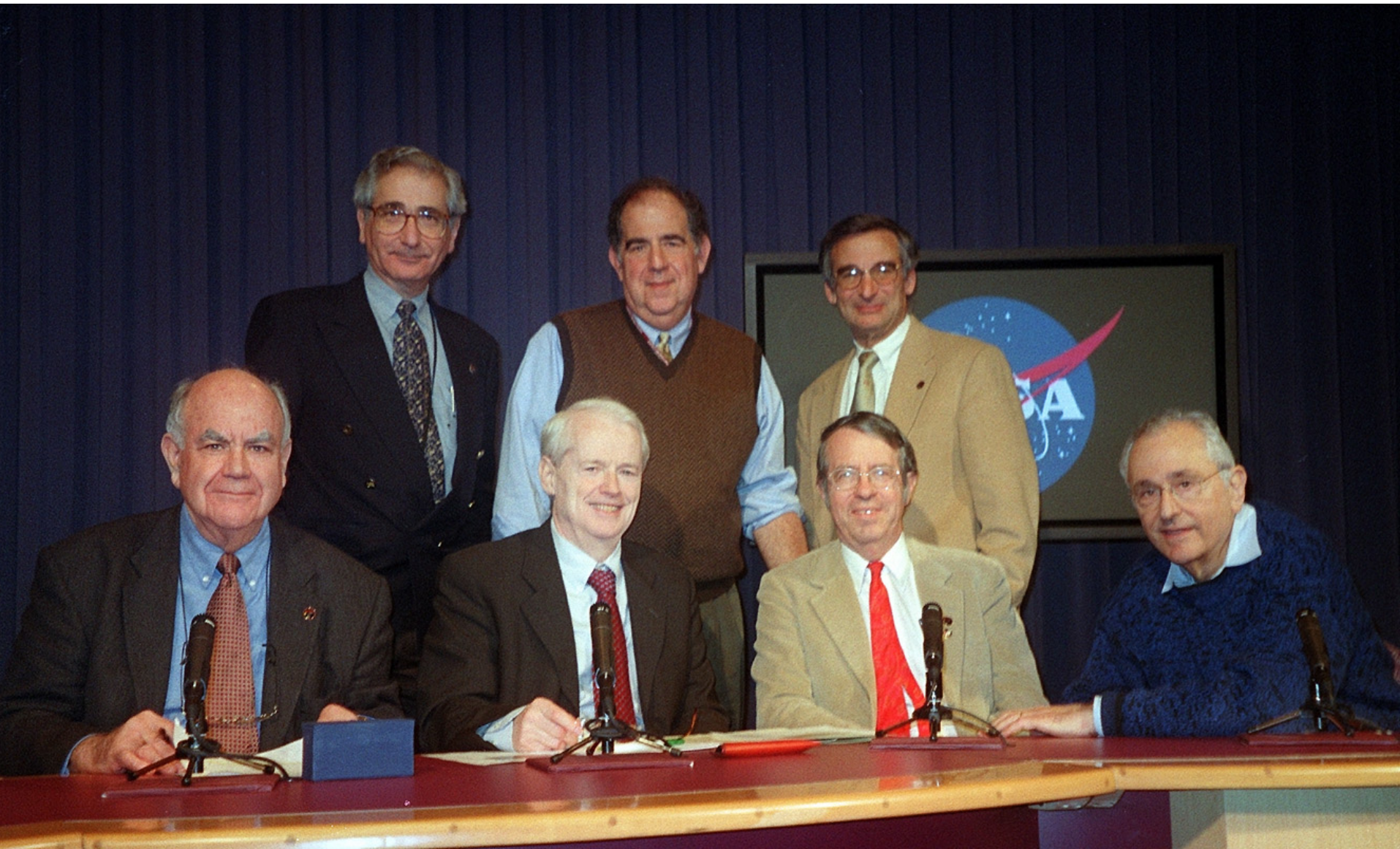
A Report to the
American Astronomical
Society

Michael Werner

*Spitzer Space Telescope Project Scientist
Jet Propulsion Laboratory/Caltech
June 1, 2004*

[SSC.spitzer.caltech.edu]





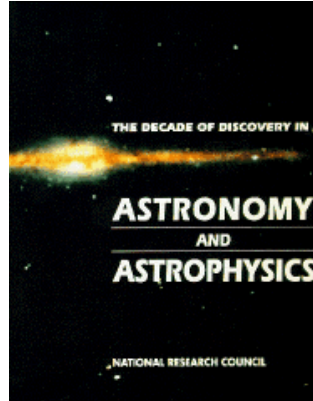


Spitzer: Promise Fulfilled!!



“The highest priority for a major new program in space-based astronomy is the Space Infrared Telescope Facility (SIRTF).”

*National Research Council,
Astronomy and Astrophysics
Survey Committee, 1991*



“SIRTF remains unparalleled in its potential for addressing the major questions of modern astrophysics.”

*National Research Council,
Committee on Astronomy and
Astrophysics, 1994*

“Taken together, the projects we recommend represent an exciting use of NASA’s next major astrophysical observatory. Each of the projects will yield superb science that we expect of a major investment of time in a NASA Great Observatory. A hallmark of each of these projects is that they fully exploit the unique and special capabilities of SIRTF that make it a major NASA mission and the highest priority space project of the 1991 National Academy of Sciences Decade Review.”

*Letter from SIRTF Legacy Science TAC Chair John Bahcall to SSC Director Tom Soifer,
November 2000*